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Arkadiusz Nowak*, Marcin Nobis, Małgorzata Gębala, Piotr Wasik

Populetum pamiricae ass. nova – an endemic forest association to Pamir in Tajikistan (Middle Asia)

Abstract: The floristic structure, distribution and habitat requirements of a forest syntaxon, *Populetum pamiricae* ass. nova is described. The potential range of the *Populetum pamiricae* association comprises the mountains of eastern Tajikistan (Pamir Alai Mts), Kashgaria in western China (Kunlun Shan Mts) and north-eastern Afghanistan (Hindu Kush Mts) in Middle Asia. The biotope of this community comprises of high mountain river valleys situated at elevations between 2,500 and 3,200 m above sea level. Phytocoenoses of the *Populetum pamiricae* association are characterized by the apparent domination in the tree layer of a diagnostic species, *Populus pamirica*. The tree stand has a mean cover around 55%. The layer of shrubs consists primarily of the willow including *Salix linearifolia* and *S. wilhelmsiana*, and *Hippophaë rhamnoides*, *Rosa huntica* and *Lonicera stenantha*. The herb layer is less developed and consists of species typical for *Populetea laurifolio-suaveolentis*; however, in juvenile stages of the community, taxa from riverbed vegetation (*i.e*. *Salicion eleagni*) also frequently occur. *Populetum pamiricae* grows in areas of flood inundations caused mainly by spring thaw where the humus layer in soils is very thin or even completely absent. The forest association of *Populetum pamiricae* ass. nova is one of the rarest and most rapidly disappearing wood communities in Tajikistan. High conservation priority and special management is recomended for this association.

Keywords: *Betulo-Populetalia talassicae*, alpine vegetation, Gornyi Badakhshan, syntaxonomy, Tadzhikistan

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1 Introduction

Tajikistan is a mountainous country, with the two main massifs of Pamir Alai and Tian-Shan within its borders. According to the literature and herbarium data, *ca*. 4,500–5,000 vascular plant species occur in this country [1]. This number is still increasing due to recent floristic studies with records of plant species new to Tajikistan [*e.g*. 2-9]. Also, some endemic species have recently been described from this country [*e.g*. 6,10-16]. The considerable richness and uniqueness of Tajik vascular flora is reflected by the rate of endemism. More than 30% of vascular plants species have very narrow distribution ranges and are regarded as endemics [1,17]. This is one of the most important reasons for recognising the mountains of Middle Asia as one of the thirty-four hotspots of biodiversity [18] requiring the special attention of botanists and conservationists [19].

Phytosociological research on Tajik vegetation is, however, still at the beginning stage. Very recently, several papers involving vegetation classification concerning forests [20], aquatic vegetation [21], segetal vegetation [*e.g*. 22-25] and rock vegetation [15,26,27] have been published. Few studies, with the exception of [20] have entirely devoted to a riverine forest phytocoenosis, *Populetum talassicae*, which is endemic to Middle Asia and occurs in a very restricted area in the area of the Talas valley (Kyrgyzstan) and Iskanderkul (western Tajikistan).

A greater number of publications regarding forest vegetation have been published in the twentieth

***Corresponding author: Arkadiusz Nowak:** Department of Biosystematics, Laboratory of Geobotany & Plant Conservation, Opole University, 45-052 Opole, Poland, E-mail: anowak@uni.opole.pl
Małgorzata Gębala, Piotr Wasik: Department of Biosystematics, Laboratory of Geobotany & Plant Conservation, Opole University, 45-052 Opole, Poland
Marcin Nobis: Department of Plant Taxonomy, Phytogeography and Herbarium, Institute of Botany, Jagiellonian University, 31-501 Kraków, Poland
Marcin Nobis: Laboratory of Biodiversity and Ecology, Tomsk State University, 36 Lenin Prospekt, Tomsk, 634050, Russia

century by Russian botanists. Important ecological and phenological data on forest phytocoenoses are provided by the works of Zakirov [28], Zapryagaeva [29,30] and Stanjukovich [31]. However, these works do not present complete insight into the structure of communities or their floristic diversity, nor do they consider the chorological aspects of their ranges. Rather, they only represent some basic formations of vegetation determined on the basis of so-called edificators, *i.e.* indicator species predominating in this biotope, without distinguishing separate syntaxa.

Amongst forest types noted in the central Pamir Alai Mts are distinct mesotrophic deciduous forests, also known as broad-leaved stands (so-called *chernolesya*). They occur mainly in the Hissar-Darvasian and Zeravshan Ranges and in the Eastern Tajikistan region. Because of the apparent similarity of habitat conditions they correspond to the broad-leaved forests of Central Europe from the *Querco-Fagetea* class. These stands are dominated by *Juglans regia*, *Acer turkestanicum* or *Platanus orientalis*. The general altitudinal amplitude of mesophilous forests in the Pamir Alai is between 1,200 and 2,500 m a.s.l. The phytocoenoses inhabit mainly the northern slopes of medium-height mountains. Only a few stands of *Platanus orientalis* descend to lower elevations, *ca*. 750–850 m. In the herb layer of these types of communities, *Impatiens parviflora*, *Aegopodium tadshikorum*, *Poa nemoralis* and *Dactylis glomerata* predominate [28-30,32].

As far as the riparian forest phytocoenoses are concerned, two main groups of vegetation are distinguished. In the lowlands, at *ca*. 300–600 m a.s.l., the so-called *tugay* subtropical tree stand has been described, while at higher elevations (approx. 800–2,800 m) the birch and ash forests, or so-called *bielolesya*, have been defined. A tugay forest is a community of hygrophilous and thermophilous deciduous trees, mainly *Populus euphratica* (= *P. diversifolia*) and *Populus pruinosa*. In plots of this forest type known from south-western Tajikistan, *Elaeagnus angustifolia*, *E. orientalis*, *Tamarix hispida*, *Glycyrrhiza glabra*, *Saussurea kabadiana, Zygophyllum oxianum, Halostachys belangeriana*, *Phragmites communis* and *Erianthus ravennae* often appear. Riparian forests develop in valleys of lower-lying areas along the rivers Syr-Daria, Pyandzh and Vaksh and their tributaries [*e.g.* 33]. Because of the close relation to and floristic similarities with Irano-Turanian riverine vegetation, this type of loose forest should be classified as a member of the *Populetea euphraticae* class [34].

Bielolesya are spread over alpine landscapes, along the mountainous streams and small rivers as a narrow azonal belt of forest vegetation built of birches, willows and poplars. Among the dominant species, the highest frequencies and constancy are achieved by *Betula pamirica*, *B. alajica*, *B. ovchinnikovii*, *B. saposhnikovii*, *B. turkestanica*, *B. tadshikistanica*, *Salix wilhelmsiana*, *S. pycnostachya*, *S. capusii*, *S. excelsa*, *S. iliensis*, *Populus nigra*, *P. bahofenii* and *P. talassica*. As an admixture in the tree stand as well in the shrub and herb layers, *Juniperus semiglobosa*, *Sorbus tianschanica*, *Lonicera coerulea*, *Trichophorum pumilum*, *Euphrasia tatarica* and *Trifolium pratense* appear. The birch forests are usually characterized by a comparatively rich herb layer; however, especially in the higher elevations of the Pamir, the total cover of herbs is very scant [28-30,35].

From the western Pamir, a stand of *Populus pamirica* has been described which was found in alpine river valleys at altitudes of around 2,000–3,000 m a.s.l. (Figure 1). As an admixture of the tree layer, *Betula pamirica*, *Salix turanica* and *Hippophaë rhamnoides* achieve a considerable share. In the undergrowth, *Ribes meyeri and Rosa huntica* were frequently noted. It is one of the rarest types of riparian forest, which covers very little area in Tajikistan and is restricted in occurrence to several valleys in the Western and Eastern Pamirian geobotanical regions. The herb layer consists of *Astragalus tibetanus*, *Juncus thomsonii*, *Poa pratensis*, *Veronica biloba*, *Eremopoa persica*, *Polygonum coriarium*, *Artemisia sacrorum*, *Lindelofia macrostyla*, *Handelia trichophylla*, *Nevskiella gracillima* and *Trifolium repens*. The mean height of the main tree stand is approximately 6–8 m; however, the higher the elevation, the shorter the trees. At 3,000 m a.s.l., the average height is not more than *ca*. 4 m [30].

The aim of this paper is to provide a detailed phytosociological study of the community of riparian forest dominated by *Populus pamirica* and the position of this phytocoenosis in syntaxonomic classification. The present paper includes the current chorology of the community in the area of Tajikistan and its composition of species as well as habitat conditions for its occurrence.

2 Methods

2.1 Study area

The area of Pamir extends in eastern Tajikistan in some mountain ranges crossing the borders of western China, southern Kyrgyzstan and northern Afghanistan. The area of the hilly plateau and high mountain ridges is approximately 50,000 km^2 (Figure 1). According to a recently published bioclimatic classification of the earth, which considers mainly precipitation and temperature values, the study area should be classified within the

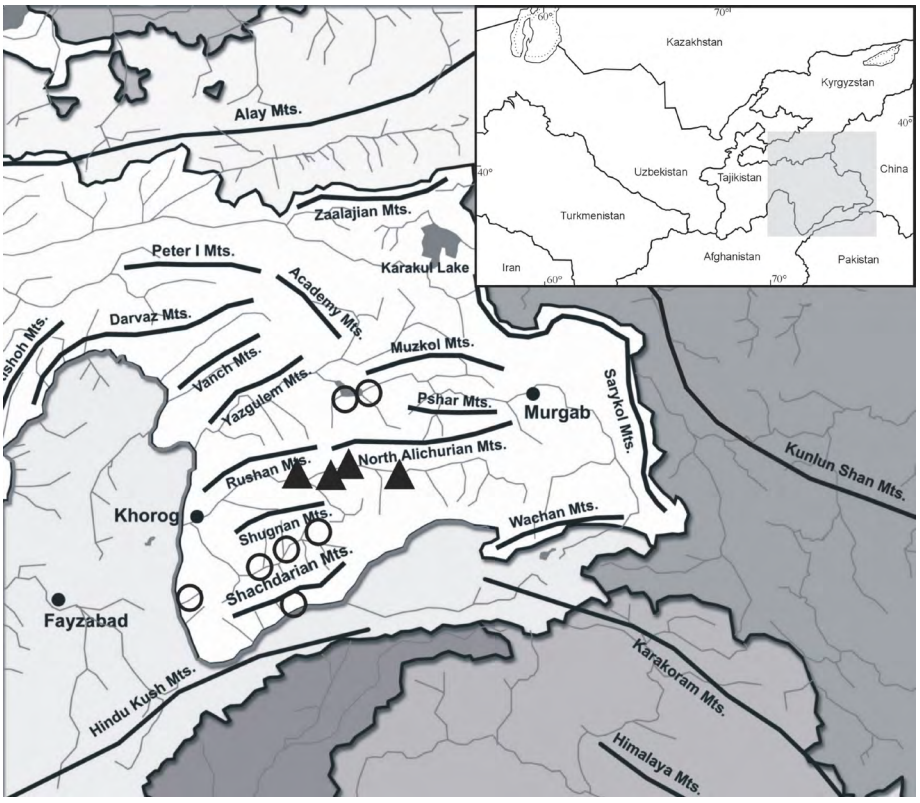

Figure 1: The location of Pamir in Middle Asia

Mediterranean type of macrobioclimate. This type of climate is characterized by a summer drought lasting for at least two consecutive months in which P < 2T [36]. In the case of Dushanbe, four months in the summer period match this condition (Figure 2). Also, other bioclimatic features of the study area classify it within the Mediterranean macrobioclimate. The yearly average temperature is below 25°C (2°C) and the Compensated Thermicity Index is below 580 (80). The Continentality Index is Ic=31; thus, our study area fits the continental type (eucontinental subtype). The Ombrotype Index (Io=14) confines the study area within the upper humid horizon. According to thermotype thresholds, the Khorogh region should be classified as an upper oromediterranean zone. As is typical for a Mediterranean climate, the area has a generally high level of solar radiation, as well as a low percentage of cloud cover, high-amplitude annual temperatures, and moderate humidity and precipitation, with the exception of the spring period, when there is a considerable amount of rainfall (Figure 2). In the south-western regions of Tajikistan, average June temperatures reach around 30°C. In the temperate zone and alpine elevations, average temperatures in midsummer range between 9.7°C and 13.5°C. Annual precipitation ranges in Tajikistan from *ca*. 70 mm (in the mountainous deserts of the eastern Pamir and southwestern lowlands of the country) to *ca*. 600 mm (on the southern slopes of the Hissar Range). The limit of perpetual snow is at an altitude of 3,500–3,600 m a.s.l. in the western Pamir Alai Mts, rising to about 5,800 m a.s.l. in the highest elevations of the eastern Pamir [37,38].

The study was conducted in the eastern part of Tajikistan, in the West and East Pamirian geobotanical subregions (Figure 1). The studied vegetation patches were located between 2,600 and 3,200 m a.s.l. (mean 2,850). They were developed on different types of soil substrate, with a range of pH reactions between 7.1 to 8.2.

2.2 Data and analyses

The field research was conducted in 2011 and 2013. Vegetation plot size was delimited so as to represent the full floristic composition of the phytocoenosis, varying from 150 to 250 m^2 depending on plant density and homogeneity of vegetation cover. For each vegetation plot all vascular plant species were recorded according to the Braun-Blanquet method, as the most relevant in analysis of the vegetation variability [39]. The percentage value of summarized species cover was computed automatically by JUICE program [40]. Geographical coordinates, elevation above sea level, aspect and slope inclination were noted for each relevé performed. Hydrogen ion concentrations

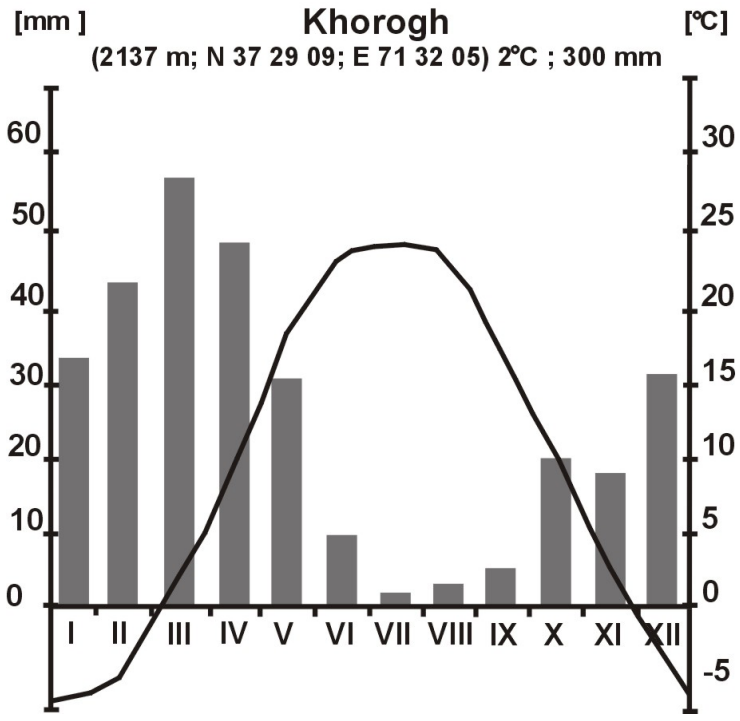

Figure 2: Climatic characterisation of the study area according to the Dushanbe weather station

were measured in aqueous rock solution using the ELMETRON CP-105 pH meter.

To find out the relation of *Populetum pamiricae* plots to other forest phytocoenoses of Pamir Alai Mts, they were pooled together with 113 plots representing communities with domination of *Populus talassica*, *P. tadshikistanica*, *P. bahofenii*, *Salix capusii*, *S. linearifolia*, *Fraxinus sogdiana*, *Ulmus minor*, *Juglans regia*, *Platanus orientalis*, *Acer turkestanica*, *Betula tianschanica* and *B. seravschanica*. All the relevés were stored in a database using the JUICE program [40]. Initial analysis showed a clear unimodal response, allowing us to use a Detrended Correspondence Analysis (DCA) with the floristic data set (presence-absence data, no downweighting of rare species) to check the floristic-sociological classification and to show the relationships between the groups. For the ordination, CANOCO for Windows 4.5 was used [41].

In the analytic table (Table 1), species constancies were classified into classes I–V [42]. The newly presented syntaxon was proposed according to the International Code of Phytosociological Nomenclature [43]. In distinguishing and ranking the association, the works of Nowak & Nobis [20], Hilbig [44] and Wehrden *et al.* [45] were taken into account. The association concept follows Willner [46].

Species nomenclature mainly followed Cherepanov [47]. Plant material collected during field studies was deposited in the Herbarium of Middle Asia Mountains, hosted in OPUN (Opole University, Poland) and KRA (Jagiellonian University, Poland).

3 Results

3.1 Syntaxonomic position of the association

In Tajikistan the community of *Populetum pamiricae* occurs on slopes in the oromediterranean elevation, in wet places with peaty soils. Its syntaxonomic position is as follows:

- Cl. *Populetea laurifolio-suaveolentis* Hilbig 2000
  - O. *Betulo-Populetalia talassicae* A. Nowak & M. Nobis 2013
- All. *Populion talassicae* A. Nowak & M. Nobis 2013
  - Ass. *Populetum pamiricae* A. Nowak & M. Nobis ass. nov. (holotypus hoc loco, Table 1, rel. 1)

The *Populetea laurifolio-suaveolentis* class consists of plant communities occupying the wings of river valleys, mostly mountainous (at least not in the broad low-lying valleys of great rivers) with a large share of meadow species in the undergrowth and the relatively low tree density. The distribution range of that class is not fully known, but undoubtedly includes Middle and Central Asia [20]. In the Pamir Alai mountains the most important diagnostic taxa for this vegetation type are *Poa*

Table 1: Association of *Populetum pamiricae* ass. nova in Pamir (Tajikistan, Middle Asia)

Successive number of relevé	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	CONSTANCY
day	21	21	21	21	3	3	3	3	3	3	3	3	
Date: month	8	8	8	8	6	6	6	6	6	6	6	6	
year	13	13	13	13	11	11	11	11	11	11	11	11	
Longitude	374214	374214	374230	374230	374408	374408	374408	374215	374215	374215	374320	374319	
Latitude	722405	722405	715354	715354	720934	720934	720934	715605	715605	715605	721439	721439	
Altitude (m)	3198	3198	2640	2638	2900	2900	2935	2655	2678	2650	3030	3034	
Cover of tree layer a [%]	70	65	45	70	70	50	65	70	50	70	30	40	
Cover of tree layer a2 [%]	1	5	5	15	15	40	30	20	5	35	5	15	
Cover of shrub layer b [%]	50	20	5	5	20	35	45	40	20	35	10	40	
Cover of herb layer c [%]	70	65	65	15	5	5	20	2	10	15	20	15	
Relevé area [m²]	200	250	200	200	150	150	200	200	250	200	150	250	
Locality	Mardz	Mardz	Berdibekobod		Gunt	Gunt	Gunt	Vodzh	Vodzh	Vodzh	Vankala	Vankala	
pH	8,1	7,9	7,2	7,5	7,1	8	7,5	8	7,6	8,1	7,7	8,2	
Species number	11	11	22	18	9	9	15	7	11	11	10	13	
Ch. Ass. Populetum pamiricae													
Populus pamirica a	4	4	3	4	4	3	4	4	3	4	3	3	V
Populus pamirica b	3	2	1	.	1	1	+	1	2	1	1	2	V
Ch. All Populion talassicae													
Astragalus tibetanus	2	3	+	.	+	.	.	.	.	.	.	+	II
D. Cl. Populetea laurifolio-suaveolentis													
Agrostis alba	2	1	1	.	+	+	1	.	+	+	.	.	IV
Rosa huntica b	2	1	.	+	.	.	.	+	.	.	.	+	III
Poa pratensis	2	1	.	.	+	.	.	.	.	.	.	.	II
Trifolium repens	2	.	2	.	.	.	.	.	.	.	.	.	I
Trifolium pratense	.	.	.	1	.	.	.	.	.	.	.	.	I
Others	.	.	.	.	.	.	.	.	.	.	.	.	
Hippophaë rhamnoides a2	+	1	1	2	2	3	3	2	1	3	1	2	V
Hippophaë rhamnoides b	+	+	+	1	1	1	1	2	1	3	+	.	V
Calamagrostis pseudo-phragmites	.	.	1	1	1	+	.	+	+	1	.	1	IV
Carex stenophylloides	.	.	.	+	.	+	+	+	1	1	1	.	III
Lactuca tatarica	2	2	+	.	+	.	.	.	.	.	1	1	III
Poa relaxa	.	.	.	.	+	1	+	+	.	.	1	+	III
Astragalus sp.	.	.	.	.	.	+	+	.	+	.	1	1	III
Salix linearifolia b	.	.	1	2	1	1	.	.	.	.	.	.	II
Conringia planisiliqua	.	.	.	.	.	.	1	.	.	+	.	+	II
Nevskiella gracillima	.	.	.	.	.	.	1	.	+	.	.	+	II
Artemisia persica	.	.	.	.	.	.	+	+	.	.	+	.	II
Artemisia santolinifolium	.	.	+	+	.	.	.	.	+	.	.	.	II
Potentilla orientalis	.	.	.	.	.	.	.	.	+	+	+	.	II
Roegneria schugnanica	1	+	.	.	.	.	.	.	.	.	.	.	I
Elymus multicaulis	+	1	.	.	.	.	.	.	.	.	.	.	I
Hippophaë rhamnoides c	.	.	.	.	+	.	1	.	.	.	.	.	I
Leptorhabdos parviflora	.	.	1	+	.	.	.	.	.	.	.	.	I
Salix turanica a	.	.	+	1	.	.	.	.	.	.	.	.	I
Salix wilhelmsiana b	+	.	.	.	.	.	.	.	.	.	+	.	I
Ferula sp.	.	.	.	.	.	.	+	.	.	+	.	.	I
Carex pachystylis	.	.	.	.	.	+	.	.	.	.	.	+	I
Sapponaria griffithiana	.	.	+	+	.	.	.	.	.	.	.	.	I
Lonicera stenantha	.	.	.	.	.	.	.	.	.	+	+	.	I
Piptatherum sp.	.	.	.	.	.	.	.	.	+	.	.	+	I
Sisymbrium altissimum	.	.	.	.	.	.	.	.	.	+	.	+	I

Sporadic species: *Acantholimon* sp. 7; *Artemisia dracunculus* 7; *Artemisia pamirica* 4(1); *Blysmus compressus* 3(1); *Bromus tectorum* 10; *Carex songarica* 3(1); *Chenopodium botrys* 4; *Chondrilla canescens* 4(1); *Cirsium arvense* 3; *Epilobium minutiflorum* 3(1); *Equisetum arvensis* 3(3); *Equisetum ramosissimum* 3(1); *Eragrostis minor* 4; *Erigeron acris* 4; *Euphrasia pectinata* 3; *Hyalea pulchella* 4; *Juncus articulatus* 3; *Lappula* sp. 7; *Lindelofia macrostyla* 3; *Myricaria squamosa* 3; *Oxytropis capusii* 7(1); *Poa bulbosa* 2; *Poa nemoralis* 2; *Polygonum coriarium* 4; *Scorzonera inconspicua* 9; *Stipa orientalis* 7.

pratensis and *Vicia tenuifolia*. Most species making up the communities in Middle Asia from the order *Populetalia laurifolio-suaveolentis* belong to a circumboreal element, however as diagnostic for vegetation plots in Tajikistan, the species with an Irano-Turanian distribution has been assigned. They relatively often occur along mountain rivers and composing so-called *bielolesya* - river carrs with *Betula seravschanica*, *B. ovchinnikovii*, *B. procurva* subsp. *sogdiana*, *B. turkestanica*, *B. saposhnikovii* subsp. *murgabica* and *B. tianschanica*. Within the order, the alliance of *Populion talassicae* is singled out. This includes the poplar forest communities developing in the higher elevations of mountain rivers with swift current or in the estuary areas of mountain lakes. Species proposed as characteristic for this alliance are *Pedicularis dolichorhiza* and *Astragalus tibetanus* [20].

3.2 Floristic structure, ecology and habitat preferences of *Populetum pamiricae*

Plots of *Populetum pamiricae* are apparently dominated by *Populus pamirica*; however, the tree stand is not dense and the main diagnostic species have cover values from around 30 to 70%, with an average of around 55%. The contributing species to the highest layer of phytocoenoses achieve insignificant shares, up to *ca*. 5% (in the case of *Salix turanica*). Shorter trees such as *Hippophaë rhamnoides* (a subcanopy a_2 layer) in a few cases form a relatively dense canopy with approximately 50% total cover value.

The layer of bushes reaches coverages of between 5 and 50%, consisting primarily of willow species, *Salix linearifolia* and *S. wilhelmsiana*, as well as of *Hippophaë rhamnoides*, *Rosa huntica* and *Lonicera stenantha*. In the undergrowth, *Populus pamirica* occurs relatively commonly, although in small quantities does not exceed 25%.

The herb layer of *Populetum pamiricae* is rather species-poor. Only in the case of more humid variants of the association does the species richness of herbs reach 18 taxa. In these plots, the plants typical for *Populetea laurifolio-suaveolentis* occur, e.g. *Astragalus tibetanus*, *Poa pratensis*, *Trifolium pratense* and *T. repens*. In other phytocoenoses, located alongside riverbeds, plants typical for riverbed shrubs occur with significant abundance and frequency, e.g. *Hippophaë rhamnoides*, *Calamagrostis pseudophragmites*, *Myricaria squamosa*, *Equisetum ramosissimum* and others (Table 1).

Separate plots of this community are relatively diverse in terms of floristic richness. In phytosociological relevés, between 7 and 22 species were noted. The total number of taxa noted in the plots of studied community reached 55 species (Table 1).

The detrended correspondence analysis shows the relation of *Populetum pamiricae* to other forest communities of Pamir Alai Mts (Figure 3). The association is clearly distinct from other forest vegetation due to different species composition. The most similar associations in terms of environmental conditions (mainly altitude and soil type) are communities of *Salix capusii*, *S.*

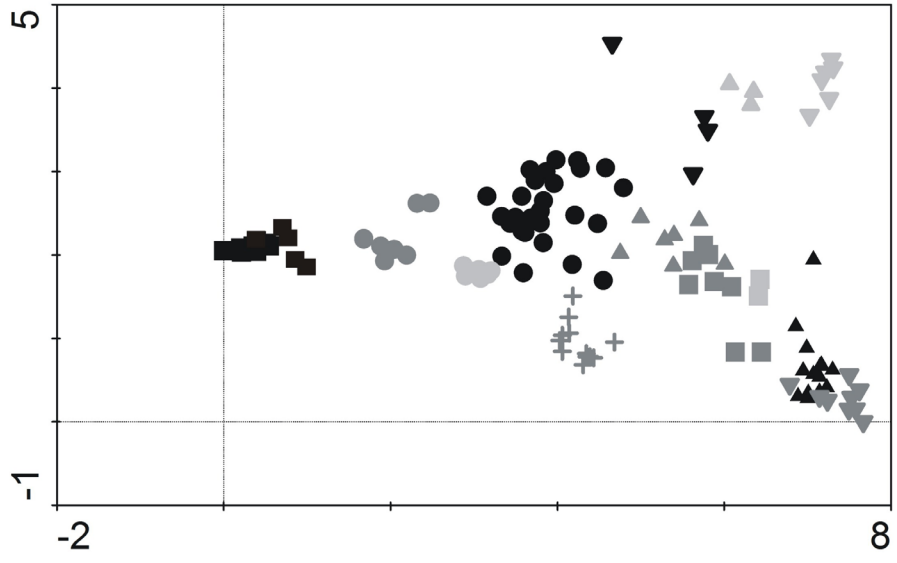

Figure 3: DCA ordination for samples of forest communities in Tajikistan (N=125). ●*Populetum talassicae*, ●Comm. of *Salix capusii*, ●Comm. of *Salix linearifolia*, ■ *Populetum pamiricae*, ■ Comm. of *Populus tadshikistanica*, ■ Comm. of *Populus bahofenii*, ▲Comm. of *Juglans regia*, ▲Comm. of *Fraxinus sogdiana*, ▲ Comm. of *Ulmus pumila*, ▼Comm. of *Betula tianschanica*, ▼Comm. of *Acer turkestanica*, ▼Comm. of *Platanus orientalis*, + Comm. of *Betula seravschanica*.

linearifolia and *Populus talassica*. However, the *Populetum pamiricae* has the highest altitudinal distribution and species poor herb layer reflecting harsh microclimate conditions. In central section of the ordination graph the more fertile and moderately rich in species riverside plant communities have been depicted. Among them the plots with domination of *Betula tianschanica*, *B. seravschanica*, *Populus tadshikistanica* and *Fraxinus sogdiana*. Further to the right, with increasing trophy level, the plots of mesic broad-leaved forests of deep, nutrient rich soils have been positioned. These plots represent tree stands with domination of *Juglans regia*, *Acer turkestanica* and *Platanus orientalis*.

Phytocoenoses of the *Populetum pamiricae* community create green riverine belts along the edges of alpine rivers and streams (Plate 1). These are composed of small surface thickets in several sections of the Bartang, Gunt, Garam Chashma, and Shakhdara River valleys. *Populetum pamiricae* is a typical high-mountain forest community occurring at an altitude of 2,600–3,200 m a.s.l. It develops mainly in oromediterranean elevations on river valley floors close to riverbeds. The alpine character of the association is highlighted by a considerable contribution of typically mountainous species in association plots, such as *Astragalus tibetanus*, *Artemisia pamirica*, *A. santolinifolium* or *Roegneria shugnanica*. The humus layer of soils is very thin (up to 10 cm) or even completely absent (skeletal or residual soils). In general, the community develops in areas of flood inundations caused mainly by spring thaws. This causes intensive deposition of pebbly material and as a result, there is scant herb coverage, inhibited by the accumulation of a thick gravel layer. In all cases, the soil environment has an alkaline reaction, sometimes pH > 8.

Plate 1: *Populus pamirica* and *Populetum pamiricae* ass. nova in Gunt valley (Western Pamir, Tajikistan)

3.3 Distribution

The potential range of the distribution of the *Populetum pamiricae* community is defined by the range of its main diagnostic species, *i.e*. *Populus pamirica*. It is limited by the mountains of eastern Tajikistan (Pamir Alai), Kashgaria in western China (Kunlun Shan) and north-eastern Afghanistan (Hindu Kush) [48]. In Tajikistan, tree stands of *Populetum pamiricae* occur in a very limited area, mainly in the Gunt River valley (between Murghab and Khorog). As mentioned above, the optimal altitudinal distribution of this community lies approximately between 2,600 and 3,200 m a.s.l. Other locations of *Populus pamirica* have been spotted during our research in neighbouring valleys (e.g. Khuf or Shakhdara); however, the species does not develop mature tree stands but rather small tree groups or loose coppices in a mosaic of *Salix* sp. riverside communities. Unfortunately, due to intensive forest cutting in last decades, in many locations where *Populus pamirica* previously occurred, the species has recently disappeared [49,50]. The easily accessible habitat of *Populetum pamiricae* and the surroundings, densely inhabited narrow river valleys with main transport routes, explain why this type of forest has been significantly reduced and degraded in last years. The former area of occupancy of *Populetum pamiricae* has been converted to pastures, fields or human settlements.

4 Discussion

At present, the main area of occurrence of *Populetum pamiricae* in Tajikistan is the middle section of the Gunt River valley. Explorations in neighbouring valleys, *i.e*. the Shakhdara, Murgab and Pyandzh, have not confirmed the persistence of well-developed plots of this association. Even in the Gunt valley, in many locations only juvenile phytocoenoses have been documented, with tree layers no higher than 5–6 m. This could be a reason for the significant share of species typical for riverbed shrub vegetation from the *Salicion eleagni* alliance. This group is represented by *Calamagrostis pseudophragmites*, *Hippophaë rhamnoides*, *Equisetum ramosissimum*, *Myricaria squamosa* and *Saponaria griffithiana*. These species find optimum habitat conditions in neighbouring thicket formations on gravels of alpine streams. However, if the human impact (cutting and grazing) has hampered the development of trees, they expand and increase in abundance. Despite this overdeveloped shrub layer, we decided to classify *Populetum pamiricae* within the *Populion talassicae* alliance, because the most mature stands reveal a significant similarity in floristic structure, mainly the great contribution of meadow species and presence of *Astragalus tibetanus*. *Populetum pamiricae* is a climax, last stage of developement of the riverrine vegetation in oromediterranean elevations of western Pamir in Tajikistan.

Populetum pamiricae should be included in the *Populetea laurifolio-suaveolentis* class because of habitat similarities, i.e. occupation of the bed areas of mostly mountainous river valleys, and floristic congruences, for example, a large share of meadow species in the undergrowth and relatively low tree density [44]. The considerable contribution of meadow plants is probably caused by the long-standing practice of grazing and mowing of ground vegetation in Tajik forests. The community of *Populetum pamiricae* is the geographical vicariant of communities with a predominance of *Populus talassica* known from the western Pamir Alai [20] and *Populus laurifolia*, described from the central Tian Shan as the association occupying habitats close to mountain rivers in contact with the riverbed vegetation of *Salix* sp., *Tamarix* sp. and *Myricaria* sp. [51].

The *Populetum pamiricae* is clearly distinct from other forest vegetation mainly because the species composition. Together with communities of *Salix capusii*, *S. linearifolia* and *Populus talassica* it constitute the *Populion talassicae* alliance which is characterized by a considerable share of species like *Astraglaus tibetanus*, *Poa pratensis*, *Vicia tenufolia* and other meadow plants. *Populetum pamiricae* is the extreme type of that riverside vegetation, having the highest altitudinal distribution and species poor herb layer reflecting harsh microclimate conditions. Other reason for that floristic scarcity is quite unfertile habitat of the riverside areas in oromediterranean elevations. The plots of *Populateum pamiricae* are clearly distinct to those with domination of *Betula tianschanica*, *B. seravschanica*, *Populus tadshikistanica* and *Fraxinus sogdiana* which occupy more fertile habitats in lower elevations. They also significantly differs from mesic broad-leaved forests of deep, nutrient rich soils built by *Juglans regia*, *Acer turkestanica* or *Platanus orientalis*. They occupy mainly northern slopes within montane and submontane zone.

Populetum pamiricae significantly differs also from phytocoenoses of tugay forest known from south-western Tajikistan. Stands of *Populus pruinosa* develop in much warmer and drier climates, which is reflected in the different floristic composition of undergrowth and seasonal dynamics of the species. It seems reasonable to include the tugay forest in the class *Populetea euphraticae* which occurs more often in low-lying broad river valleys (*e.g.* Amu-Daria) and desert oases [44,45,52].

Unlike riverbed thickets from the *Salicion eleagni* or *Epilobion fleisheri* alliances, the association of *Populetum pamiricae* develops in locations with fewer dynamic processes of alluvial deposits. In the oldest tree stands, the topsoil humus layer was observed as it was in the case of *Populetum talassicae* [20]. Only in the locations closest to riverbeds or in areas of recent inundation was the soil underdeveloped or even absent. In these cases the low availability of organic matter and atrophy of the habitat are reflected in species scarcity. However, this seems to be a natural variation in these alpine phytocoenoses, which have to be well adapted to periodic fluctuations in flow levels.

Populetum pamiricae is a very rare and endemic plant community of the highest elevations in the eastern Pamir Alai Mts. Higher up, the extremely harsh climate, in particular the very short vegetation season, excludes the development of broad-leaved forests. Therefore, the community is essential in researching the altitudinal range of communities, including their relationships to climate change [53,54].

At present, the extent of occurrence of *Populetum pamiricae* in Tajikistan comprises the middle section of the Gunt River valley, which is entirely included in Gornyi Badakhshan National Park. This is unfortunately an ineffective method of legal preservation and the area of occurrence of the association is continually decreasing. So, given the evidence of rapid disappearance of this kind of forest vegetation, there is a great need to implement adequate measures to effectively protect the last plots of *Populetum pamiricae* in the world. In Tajikistan, the remaining forest patches of Pamirian poplars cover no more than 5–10% of their initial extent. At present they barely reach a total of *ca*. 300 ha of mature tree stands.

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